INVESTIGATIONS OF

SHINGLE TOW PACKING MATERIAL FOR CONIFER SEEDLINGS

KENNETH W. KRUEGER

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
U.S.D.A. Forest Service Research Paper PNW-63
Portland, Oregon
1968

Cover Photo: Sprinklers installed over bales of stored shingle tow to supplement leaching from rainfall.

INTRODUCTION

Shingle tow, the stringy byproduct from the manufacture of western redcedar (*Thuja plicata* Donn) shingles, was first used about 1915 to keep tree seedling roots moist during shipment. In the decades since, shingle tow became the packing material most commonly used in Pacific Northwest forest nurseries. It has not been without critics, however.

Unexplained seedling mortality during the first season after outplanting has been frequent in the Pacific Northwest. While there are many possible causes for such mortality, shingle tow packed around seedling roots was one factor common to most planting failures. Though nurserymen could point to thousands of acres of successful plantation and feel secure in its use, the forester seeking a culprit for unexplained mortality often suspected shingle tow. Results of this investigation partially clarify the role of shingle tow as a packing material.

BACKGROUND

Only limited tests have been made on shingle tow's suitability as a packing material. In 1926, its moisture-holding capacity was determined to be adequate for shipping seedlings from Wind River Nursery to distant points in the Pacific Northwest.[1/] Mold-retarding properties, noted by Deffenbacher and Wright (1954), enhanced its popularity with nurserymen. Nonetheless, suspicions were raised by results of exploratory outplantings made in 1950 at the U.S. Forest Service's nursery at Bend, Oreg. Only 33 percent of ponderosa pines whose roots had been immersed for 3 hours in the leachate from a tank used to wet shingle tow survived the first growing season, compared to 90-percent survival for untreated seedlings. A slightly larger test was made to compare survival of ponderosa pine following packing of seedlings in shingle tow and sphagnum moss. Seedling survival following 2 weeks' storage favored shingle tow, but after 4 or 6 weeks' storage, survival of seedlings packed in

---

1/ Kummel, J. F. Use of shingle tow at Wind River Nursery. Unpublished report of April 30, 1926, on file at Pacific Northwest Forest & Range Exp. Sta., Portland, Oreg.

shingle tow was substantially less than for those packed in sphagnum moss. Unfortunately, the test was small and, in part of the test, survival of seedlings packed by both methods was low due to hot, dry field conditions during planting.[2/] During normal outside storage, shingle tow was leached by rainfall; following these planting trials, overhead sprinklers were installed (see cover photo). Leaching effectiveness was not explored, however, and unexplained planting failures continued.

Contentions that shingle tow could adversely affect seedlings gained support from investigations on decay resistance of western redcedar wood. At least two groups of fungicidal chemical compounds are found in the wood, the thujaplicins and water-soluble phenols (Rennerfelt 1948; Roff and Atkinson 1954). Thujaplicins are quite toxic; concentrations as low as 10 to 20 p.p.m. strongly inhibit spore germination and growth of fungi (Rennerfelt 1948; Rennerfelt and Nacht 1955). Explanations proposed for the physiological action of thujaplicins would lead one to predict toxicity to most organisms (Lyr 1961; Raa and Goksøyr 1965). While substantially less toxic to fungi than thujaplicins, water-soluble phenols occur in cedar heartwood at much greater concentrations. Thujaplicin and water-soluble phenol concentrations up to 12,000 and 233,000 p.p.m., respectively, on an ovendry basis have been found in western redcedar, but concentration varies widely between and within individual trees (Gardner and Barton 1958; MacLean and Gardner 1956a).

Exploratory experiments established that solutions leached from cedar containing thujaplicins or water-soluble phenols were damaging to Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings. Most 2-month-old seedlings died after their roots were immersed for 74 hours in 160-p.p.m. thujaplicin solution or in 1,000-p.p.m. water-soluble phenol solution. In another test, over 70 percent of dormant 2-year-old seedlings whose roots were immersed in a 65-p.p.m. solution of thujaplicins for 48 hours died in the following 60 days. Every seedling was affected to some degree (Krueger 1963). In light of the accumulated information, more intensive evaluation of shingle tow appeared needed.

EXPERIMENTAL

The possible relation between use of shingle tow and seedling mortality was studied by (1) further testing toxicity of extractives from shingle tow, (2) examining conditions causing seedling mortality, and (3) assessing certain nursery conditions influencing amount of toxic compounds available.

Investigation focused mainly on thujaplicins since water-soluble phenols

---

[2/] Tarrant, R. F., Isaac, L. A., and Mowat, E. L. Unpublished progress report on Deschutes 1950 test on ponderosa pine field planting. February 7, 1951. On file at Pacific Northwest Forest & Range Exp. Sta., Portland, Oreg.

appear to cause damage only at high concentrations and are largely uncharacterized for western redcedar. Analyses for thujaplicin were made by the method of MacLean and Gardner (1956b).

Toxicity of Extractives

Thujaplicin solutions used in seedling toxicity tests (Krueger 1963) were not pure but contained other extractives. Hence, two experiments were made using pure materials.

First, the effect of γ-thujaplicin[3/] on respiration of Douglas-fir roots was measured in a Warburg respirometer. Pieces 5 mm. long were cut from actively growing white root tips of seedlings 15 to 35 days old. Approximately equal numbers of pieces were placed in individual Warburg flasks, each containing 2 ml. of M/45 potassium citrate buffer at pH 5.0. Oxygen uptake was determined at 30° C. for four flasks of each concentration. After a 2-hour calibration period, 0.5 ml. of thujaplicin solution or water was tipped in, and measurements were continued for 6 more hours. Adjustments made for initial differences in flask volumes and initial respiration rates were less than 4 percent. Low concentrations of γ-thujaplicin depressed respiration of actively growing Douglas-fir roots (fig. 1). B-thujaplicin also lowered respiration.

Second, root systems of 10 actively growing 1-0 Douglas-fir seedlings were immersed in a 20 p.p.m. solution of pure B-thujaplicin or in distilled water for 96 hours. The seedlings were then replanted in vermiculite and grown in a growth chamber for 103 days under 20° C. day-10° C. night temperature and 16-hour day length. Twenty percent of the seedlings whose roots had been immersed in B-thujaplicin solution died; all controls lived. Three of the seedlings which survived the 20-p.p.m. concentration had shortened needles on new growth or browning at the base of needles.

In previous experiments with extractives, either the thujaplicin or phenol fraction was tested in solution. In combination, the two fractions can also kill, as shown when seedlings were placed with their roots in moist western redcedar sawdust for a week, then potted in vermiculite. All seven seedlings placed in unleached sawdust subsequently died, while all those placed in previously leached sawdust lived. Presumably, the harmful effect of thujaplicins and water-soluble phenols is additive; synergism is also possible.

3/ The principal thujaplicin isomers in western redcedar are B- and γ-thujaplicin, 2-hydroxy-4-, and 5- isopropyl-2,4,6-cycloheptatriene-1-one, respectively. Samples were graciously furnished by J. A. F. Gardner, Canadian Department of Forestry, Vancouver, British Columbia, and by David Goheen, Crown Zellerbach Corp., Camas, Wash.

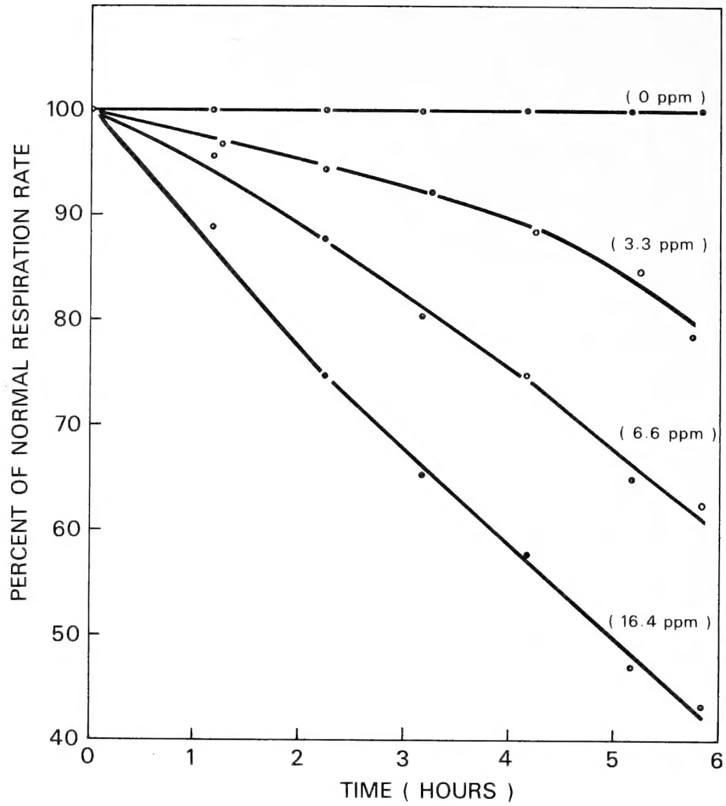

Figure 1.—Solutions of γ-thujaplicin depress respiration of Douglas-fir root tips in M/45 citrate buffer, pH 5.0 at 30° C.

Conditions Causing Seedling Mortality

Obviously, seedlings must take up toxic chemicals for mortality to occur. All tests described so far were under temperature and light conditions conducive to high transpiration and water uptake. Conditions for minimum uptake were simulated by placing 2-0 Douglas-fir seedlings in darkness at 8° C. (46° F.) with roots immersed in solutions of B-thujaplicin. Solutions ranged from 0 to 30 p.p.m.; the 30-p.p.m. concentration contained about 1 mg. thujaplicin per seedling. After 72 hours, seedlings were removed from the test conditions, planted in vermiculite, and placed in the greenhouse. After 100 days, mortality was 0, 7, 13, and 0 percent for groups of 15 seedlings whose roots had been immersed in B-thujaplicin solutions of 0, 20, 25, and 30 p.p.m., respectively. Under conditions where transpiration is low, little thujaplicin apparently enters the plants and hence few, if any, die. Water uptake and transpiration are not the only consideration, however--as shown by the following experiments.

If seedling mortality was directly related to quantity of thujaplicin taken

up, better extrapolation between test results and field practice might be made. To test this relationship, 2-year-old seedlings weighing about 7.5 gm. fresh weight each were brought directly from the Wind River Nursery, their roots were carefully washed free of soil, and seedlings were then placed under conditions of 25° C. and 1,000 ft.-c. with roots immersed in 37-p.p.m. solutions (2.24 mg. per seedling) of mixed thujaplicins. Three replications of five seedlings each had roots immersed for 1, 3, 6, 24, or 48 hours. Roots were then removed from the solutions, drained, and seedlings were potted in sand. The remaining solutions were made to volume and analyzed for thujaplicins with uptake assumed to be the difference between starting and final concentrations.

Apparent uptake was extremely rapid as shown in figure 2. But only about 0.15 mg. difference resulted from 1- and 48-hour immersion, suggesting that most thujaplicin molecules were adsorbed on root surfaces rather than being absorbed into the plant. Mortality subsequent to immersion of seedling roots in thujaplicin solution averaged 20.1 percent greater than for seedlings whose roots were immersed in water for similar periods. Mortality was not closely correlated with either immersion time or apparent uptake. One feature of the preceding investigations thus assumed particular importance--roots of seedlings used had either been grown in sand from seed, been transplanted into sand, or tested bare rooted after washing. The effect of thujaplicins on seedlings with soil-covered roots had not been tested.

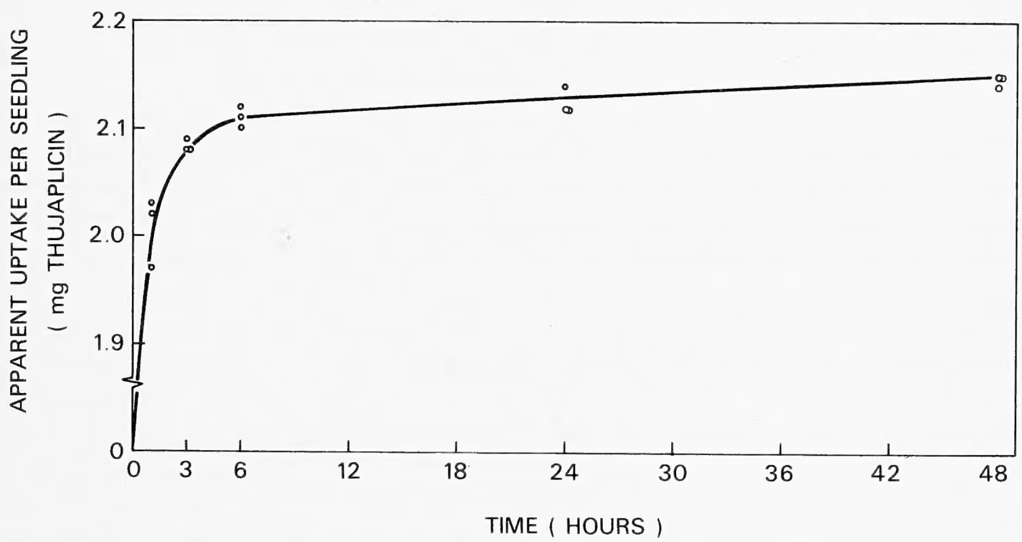

Figure 2.—Apparent uptake of thujaplicins by Douglas-fir seedlings.

Soil present on the roots might protect seedlings by adsorbing or reacting with thujaplicins present in solution. To test this possibility, a small sample of Wind River Nursery soil (Stabler shotty silt loam) was air-dried, sieved through a 60-mesh screen, and added in weighed amounts to 10 ml. aliquots of solution each containing 0.45 mg. B-thujaplicin. Solutions were stirred for 30 seconds, allowed to stand for 1 hour, then centrifuged and analyzed for the B-thujaplicin remaining in solution. About 100 mg. of this soil can almost

remove 0.45 mg. B-thujaplicin from the solution (fig. 3). Thujaplicin adsorbed on the soil could not be re-extracted with ferric acetate, indicating that the forces involved are strong.

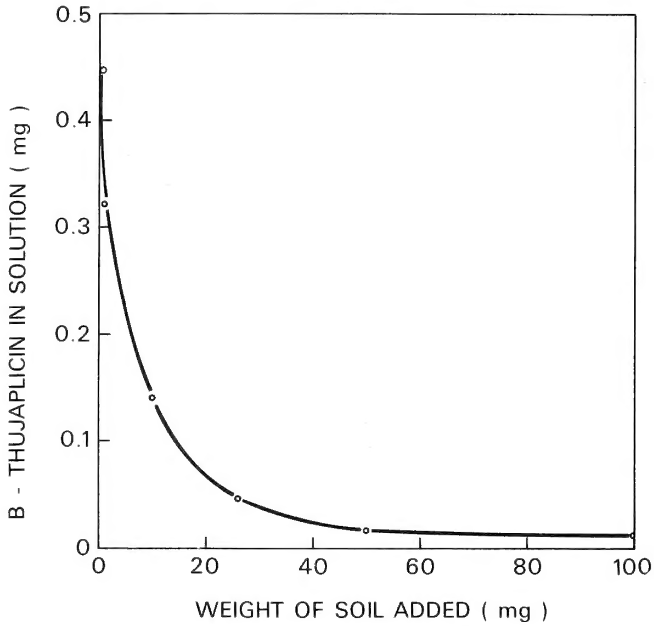

Figure 3.—Amount of B-thujaplicin remaining in solution after adding various amounts of nursery soil.

To test whether seedlings with unwashed roots would be protected by adhering soil, roots of dormant 2-0 seedlings from the Wind River Nursery were immersed from 6 to 96 hours in solutions containing 2.6 mg. of B-thujaplicin per seedling. All 180 seedlings tested, including controls, survived.

Thujaplicins Available from Shingle Tow Stored at Nurseries

Shingle tow from four different nurseries was analyzed for thujaplicin content; for seven samples it ranged from 0 to 120 p.p.m. All samples obtained from nurseries using supplemental sprinkling were low in thujaplicins, though the number of samples checked was too small to justify firm conclusions on its effectiveness.

Several factors, which are difficult to estimate in quantitative terms, regulate the amount of thujaplicins actually available for uptake by a seedling. Quantity of thujaplicins reaching solution may be only part of the total content present in shingle tow, since water used in packing and planting seedlings is cold, which reduces its extractive ability (fig. 4). The amount of water in shingle tow may vary, and the amount subsequently added varies even more

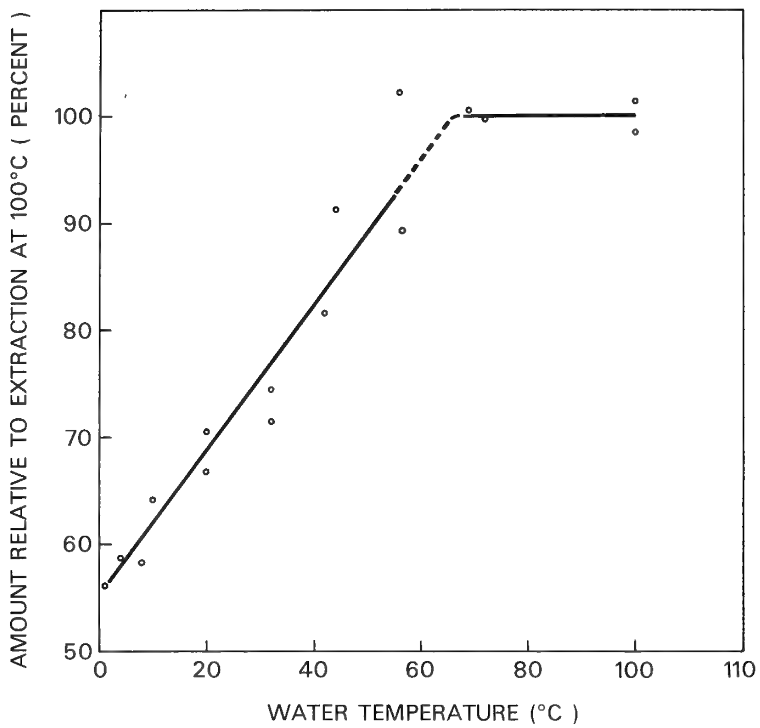

Figure 4.--Thujaplicins extracted from western redcedar sawdust with water of various temperatures. (Initial concentration- 0.55 mg. per g. cedar.)

widely depending on field conditions and the judgment of people in charge.

Nurserymen estimate that 100 bales of shingle tow will pack 1 million trees of the size used in these tests. At 25 bales per ton, a thujaplicin content of 120 p.p.m., and 50 percent extraction, an average of 0.2 mg. thujaplicins per seedling might be available for uptake. The actual amount available to an individual seedling could be much higher or lower if the starting concentration were different or if moisture distribution were uneven in the packed bundle.

DISCUSSION

Shingle tow is a potentially toxic agent--chemicals naturally present in cedar wood may kill or injure nursery seedlings. However, even when substantial amounts of toxic compounds remain in inadequately leached shingle tow, conditions favoring low uptake of these compounds or their adsorption by soil could protect seedlings packed within the tow. Field performance trials would reveal shingle tow's total effect on seedling survival and growth, but

such trials are prohibitively complex. For example, the numerous variables involved include: size, condition, and moisture content of seedlings; enviromental conditions affecting moisture loss and subsequent solute uptake by seedlings; concentration of toxic compounds in the tow; amount and temperature of water added to the tow during packing and later during seedling shipping and planting; amount of packing material used per seedling; and type and amount of soil remaining on seedling roots, which would vary by nursery and even by weather conditions prevailing during lifting. As in all field tests, weather conditions during and following planting could either totally obscure or strongly influence the magnitude of any differences in seedling survival caused by shingle tow.

Seedling mortality percentages experienced in growth chamber or greenhouse tests may have little direct relation to survival in the field where conditions are more severe. They merely foretell probabilities for field mortality. The influence of lower, but not directly fatal, concentrations of thujaplicins on seedling vigor and subsequent field survival might be seen only under stress conditions such as drought. Shortened needles and shoots observed on seedlings in some experiments make one wonder if shingle tow is a contributor to so-called "transplant shock" or "planting check."

The protection provided by soil particles is uncertain. Seedlings grown in sand, as in the first tests, may receive little or no protection from solutions of thujaplicins. Two-percent cedar sawdust of unknown content in sandy loam soil affected growth of peas (Allison, DeMar, and Smith 1963). Flowers have sometimes been killed after being mulched with fresh cedar sawdust. Soils vary widely in adsorption of organic pesticides, and thus modify their toxicity (Bailey and White 1964). Different nursery soils might also modify the toxic effect of thujaplicins in varying degree. A protective root coating provided by soil might often be incomplete since physical damage occurring to roots during lifting and root tips growing actively on Douglas-fir during the lifting season could provide sites for thujaplicin uptake.

Has shingle tow caused large-scale seedling mortality in the past? It appears unlikely, judging from thujaplicin concentrations found in shingle tow at nurseries and assuming reasonable care was taken in handling shingle tow and planting stock. An adverse effect on growth and occasional small losses of seedlings seem more likely, with larger losses being the exception. Considering the particular combination of circumstances required to produce mortality, it is easy to understand continuance of the long-standing argument between nurserymen and foresters on the merits of shingle tow.

LITERATURE CITED

Allison, F. E., DeMar, W. H., and Smith, J. H.
1963. Toxicity to garden peas of certain finely-ground woods and barks mixed with soil. Agron. J. 55: 358-360, illus.

Bailey, George W., and White, Joe L.
1964. Review of adsorption and desorption of organic pesticides by soil colloids, with implications concerning pesticide bioactivity. J. Agr. Food Chem. 12 (4): 324-332.

Deffenbacher, Forrest W., and Wright, Ernest.
1954. Refrigerated storage of conifer seedlings in the Pacific Northwest. J. Forest. 52: 936-938.

Gardner, J. A. F., and Barton, G. M.
1958. The extraneous components of western red cedar. Forest Prod. J. 8(6): 189-192, illus.

Krueger, Kenneth W.
1963. Compounds leached from western redcedar shingle tow found toxic to Douglas-fir seedlings. U.S.D.A. Forest Serv. Res. Note PNW-7, 6 pp.

Lyr, Horst.
1961. Die Wirkungsweise toxischer Kernholz-Inhaltstoffe (Thujaplicine and Pinosylvine) auf den Stoffwechsel von Mikroorganismen. Flora 150: 227-242.

MacLean, H., and Gardner, J. A. F.
1956a. Distribution of fungicidal extractives (thujaplicin and water-soluble phenols) in western red cedar heartwood. Forest Prod. J. 6(12): 510-516.

MacLean, Harold, and Gardner, J. A. F.
1956b. Analytical method for thujaplicins. Anal. Chem. 28(4): 509-512.

Raa, Jan, and Goksøyr, Jostein.
1965. Studies on the effects of the heartwood toxin B-thujaplicin on the metabolism of yeast. Physiol. Plant. 18: 159-176.

Rennerfelt, Erik.
1948. Investigations of thujaplicin, a fungicidal substance in the heartwood of *Thuja plicata* D. Don. Physiol. Plant. 1: 245-254.

Rennerfelt, Erik, and Nacht, Gertrud.
1955. The fungicidal activity of some constituents from heartwood of conifers. Svensk bot. Tidskr. 49: 419-432.

Roff, J. W., and Atkinson, J. M.
1954. Toxicity tests of a water soluble phenolic fraction (Thujaplicin-free) of western red cedar. Can. J. Bot. 32(1): 308-309.

Krueger, Kenneth W.
1968. Investigations of shingle tow packing material for conifer seedlings. U.S.D.A. Forest Serv. Res. Paper PNW-63, 10 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Western redcedar shingle tow is used extensively in forest nurseries to keep seedling roots moist during storage and shipment. Chemical compounds found in cedar wood, particularly thujaplicins, can depress root respiration or kill seedlings. Concentrations up to 120 p.p.m. thujaplicins have been found in nursery samples of tow. Soil on seedling roots can adsorb thujaplicins and moderate their influence. A number of factors affect availability and uptake and determine whether the net effect of shingle tow use will be detrimental or not.

Krueger, Kenneth W.
1968. Investigations of shingle tow packing material for conifer seedlings. U.S.D.A. Forest Serv. Res. Paper PNW-63, 10 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Western redcedar shingle tow is used extensively in forest nurseries to keep seedling roots moist during storage and shipment. Chemical compounds found in cedar wood, particularly thujaplicins, can depress root respiration or kill seedlings. Concentrations up to 120 p.p.m. thujaplicins have been found in nursery samples of tow. Soil on seedling roots can adsorb thujaplicins and moderate their influence. A number of factors affect availability and uptake and determine whether the net effect of shingle tow use will be detrimental or not.

Krueger, Kenneth W.
1968. Investigations of shingle tow packing material for conifer seedlings. U.S.D.A. Forest Serv. Res. Paper PNW-63, 10 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Western redcedar shingle tow is used extensively in forest nurseries to keep seedling roots moist during storage and shipment. Chemical compounds found in cedar wood, particularly thujaplicins, can depress root respiration or kill seedlings. Concentrations up to 120 p.p.m. thujaplicins have been found in nursery samples of tow. Soil on seedling roots can adsorb thujaplicins and moderate their influence. A number of factors affect availability and uptake and determine whether the net effect of shingle tow use will be detrimental or not.

Krueger, Kenneth W.
1968. Investigations of shingle tow packing material for conifer seedlings. U.S.D.A. Forest Serv. Res. Paper PNW-63, 10 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Western redcedar shingle tow is used extensively in forest nurseries to keep seedling roots moist during storage and shipment. Chemical compounds found in cedar wood, particularly thujaplicins, can depress root respiration or kill seedlings. Concentrations up to 120 p.p.m. thujaplicins have been found in nursery samples of tow. Soil on seedling roots can adsorb thujaplicins and moderate their influence. A number of factors affect availability and uptake and determine whether the net effect of shingle tow use will be detrimental or not.

Headquarters for the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is in Portland, Oregon. The area of research encompasses Alaska, Washington, and Oregon, with some projects including California, the Western States, or the Nation. Project headquarters are at:

College, Alaska
Juneau, Alaska
Seattle, Washington
Olympia, Washington
Wenatchee, Washington
Portland, Oregon
Bend, Oregon
La Grande, Oregon
Corvallis, Oregon
Roseburg, Oregon

The FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives – as directed by Congress – to provide increasingly greater service to a growing Nation.